

*TEMPORAL DISTRIBUTIONS OF RESPONDING  
DURING DISCRETE-TRIAL OMISSION  
TRAINING IN RATS*

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Within-session temporal distributions of responding were investigated in three experiments using rats pressing a lever in a discrete-trial omission procedure. This schedule entailed 60, one-minute trials, and a sucrose solution was made available at the end of each trial in which no lever press occurred. In Experiment I, nonnaive rats acquired and maintained responding during this training. Moreover, the probability of a response during any session showed a strong and reliable tendency to increase from the beginning to the end of the session. These results were replicated in Experiment II, using naive animals. In Experiment III, alterations were made in the training procedure, including elimination of response-contingent and noncontingent stimulus changes. Results indicate that stimulus change may be sufficient to maintain low levels of responding whether or not this change is contingent on responding.

*Key words:* omission training, stimulus-reinforcer relationships, response-reinforcer relationships, automaintenance, autoshaping, lever press, rats

The initial demonstration of autoshaping by Brown and Jenkins (1968) suggested a potential role for stimulus-reinforcer relationships in the acquisition and maintenance of operant responding. The possibility of adventitious response-reinforcer pairings in the Brown and Jenkins procedure led to investigation of variants of this procedure in which an explicit negative contingency was imposed between responding and reinforcement (Herrnstein and Loveland, 1972; Schwartz and Williams, 1972a, b; Williams and Williams, 1969). It was found that this type of procedure, usually called omission training, engendered pecking in naive pigeons and maintained pecking in previously trained birds. Such a demonstration was initially interpreted as strong support for the notion that a high correlation between a stimulus and reinforcer provided an impetus to respond, and this impetus opposed the tendency to withhold responding that would be dictated by the law of effect (see Hearst and Jenkins, 1974).

While these initial studies of omission procedures generally showed substantial and per-

sistent rates of responding, subsequent work has called this result into question. Several studies with pigeons (Barrera, 1974; Hursh, Navarick, and Fantino, 1974), crows (Powell and Kelly, 1976), monkeys (Gamzu and Schwam, 1974), and rats (Locurto, Terrace, and Gibbon, 1976; Stiers and Silberberg, 1974) have found a substantial reduction in responding under a negative contingency, and indicated that the attribution of omission-schedule behavior to stimulus-reinforcer correlation is, at best, premature. It remains unclear whether these relationships constitute a substantive causal factor in the maintenance of responding under a negative contingency. Other factors, such as stimulus change (see Herrnstein and Loveland, 1972), may play an important role in omission-schedule behavior.

The striking aspect of behavior during omission training is the persistence of moderate levels of responding even after extended exposure to the schedule. There is strong intuitive appeal to interpreting this pattern in terms of two opposing tendencies, one leading to response and one leading to no response, which are under the control of stimulus-reinforcer and response-reinforcer relationships, respectively. The strengths of these two influences could presumably vary with respect to one another as a function of the local reinforcement history during a session. In this way,

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responding would occur when stimulus-reinforcer contingencies provide the dominant source of control and responding would not occur when response-reinforcer contingencies were dominant.

A possible implication of such a formulation is that, assuming steady state, there should be a changing temporal distribution of responses seen within a session as control oscillates between the response- and stimulus-reinforcer correlations. Schwartz (1972) mentioned a waxing and waning pattern in the responding of some of the subjects in the original Williams and Williams (1969) study.

The purpose of the present study, therefore, was to analyze this temporal distribution in both naive and nonnaive subjects and to attempt to alter the distribution through manipulation of training procedures. The choice of the discrete-trial omission procedure developed by Herrnstein and Loveland (1972) offered the advantage of temporal regularity, which tended to simplify analysis. By using rats rather than pigeons, the importance of stimulus change in omission training could be evaluated in another species.

## EXPERIMENT I

### METHOD

#### *Subjects*

Five female Holtzman albino rats, approximately 140 days old at the start of the experiment, were maintained at 80% of their free-feeding weights. This 80% value was adjusted periodically to compensate for the normal weight gain seen in other rats in the colony, which were of comparable age and not food deprived. Subjects received sufficient rat chow following each training session to maintain their target weight. Water was freely available in the home cages. Each rat had an experimental history, including food-reinforced lever pressing in both free-operant and fixed-trial procedures.

#### *Apparatus*

The operant chamber and attenuation shell were of a standard type manufactured by Lehigh-Valley Company (model #142-23). The reinforcer was a saturated sucrose solution presented using a Lehigh-Valley dipper that was centrally located on the manipulandum wall of the chamber. Each operation of the dipper,

which was maintained in the withdrawn position except during reinforcement, allowed access to 0.02 ml of the sucrose solution (approximately 4 mg of sucrose). The lever was located 1.5 cm above the floor, midway between the dipper and the left-front corner of the chamber. The lever was constructed of Plexiglas, was 3.2 cm wide, and protruded 4.5 cm into the chamber. The end of the lever was covered by an aluminum sheath 2 cm long. Approximately 0.30 N was necessary to operate the microswitch attached to the lever. The lever could be transilluminated by white light of two different intensities. This was accomplished by driving light bulbs of the same type, GE #1820, with 12 or 28 V dc. Low-level illumination was provided by a 5-W houselight and white noise was always present in the chamber.

#### *Procedures*

The procedures in this experiment follow closely those presented by Herrnstein and Loveland (1972, Experiment 4). Each session consisted of 60 consecutive 1-min cycles. On a cycle in which no lever press occurred, the lever was illuminated with a trial light (T) for 59.5 sec and was then illuminated with a signal light (S) for 0.5 sec. This was followed by a 4-sec operation of the dipper, during which the timing of the trial was suspended and only the house light remained on. T and S were of different intensities, with two subjects, A and E, having a bright trial light and dim signal light, and three subjects, B, D, and F, having the opposite arrangement.

For Subjects A, B, and D, the consequence of a response during the T portion of a cycle was the immediate termination of the T light, followed by a 0.5-sec presentation of the S light, followed by blackout (B) for the remainder of the trial. In addition, the reinforcement scheduled for the end of the trial was omitted. The procedures were identical for Subjects E and F except that blackout followed a response during the T portion of the trial and the S light was on during the final 0.5 sec of the 60-sec trial. For all subjects, responses following the initial response in a trial, responses during the S portion of the trial, and responses during reinforcement had no scheduled consequences. Rats A, B, and D were given 43 daily sessions of this omission procedure and E and F were given 60 daily

sessions. Training was conducted seven days a week.

### RESULTS

Figure 1 shows the percentage of trials within each session on which a response occurred. This percentage drops off relatively rapidly during the first 15 sessions and there appears to be no systematic trend after about Session 25. Since steady-state behavior was of primary interest in this study, the final 20 sessions of Subjects A, B, and D and the final 30 sessions for Subjects E and F were used in subsequent analyses. All subjects were reliably omitting at least a quarter of the scheduled reinforcements during the later stages of training.

Some of the records presented in Figure 2 suggest that, while the level of responding continued to be quite variable, response probability increased as the session progressed. In an attempt to determine how regular and reliable this phenomenon was, all steady-rate sessions for each subject were combined to give a cumulative distribution of trials with a response (TWR) across trials. Briefly, each trial was scored 1 or 0, depending on whether a response occurred or not. The resulting matrix was collapsed across sessions to yield a vector containing the number of TWR at each trial number. This vector was divided by the total number of TWR in the matrix to provide the proportion of the total TWR that occurred during each of the 60 trials. Thus, if TWR were evenly distributed throughout the sessions (*i.e.*, no temporal trend), a plot of this function would approach a horizontal line. Figure 3 shows this distribution for each of the five subjects and the total number of TWR upon which each curve is based. While the total proportion of trials on which a response occurred is variable across the five subjects, the

relative distribution of those responses within sessions appears to be quite stable with a strong linear trend.

To determine the relative contribution of linear and higher-order components to the curves, a set of orthogonal polynomials was fit to each curve. A linear regression line fits each of the curves quite adequately, accounting for 72% of the variance, on average, with little additional contribution from the quadratic component. Second, the slopes of the five regression lines are quite close to one another, ranging from 0.020 to 0.030. It appears that most of the deviation from linearity can be accounted for by a tendency to respond during the first few trials of each session.

There is a clearly defined temporal distribution of responding that appears to be quite reliable from subject to subject. Neither the type of stimulus lights nor the ordering of S and blackout seems to have any effect on this relationship. It may be that the behavior seen on this omission procedure is an alteration of pre-existing patterns of responding. Experiment II, therefore, investigated this pattern of behavior in experimentally naive animals.

## EXPERIMENT II

### METHOD

#### Subjects

Four experimentally naive, female Holtzman albino rats, approximately 120 days old at the start of the experiment, were maintained on the same feeding schedule used in Experiment I.

#### Apparatus

The same as used in Experiment I.

#### Procedures

Each subject was given two 30-min sessions of dipper training during which the lever was removed from the chamber. In the first session, the dipper was held in the raised position until the animal drank its contents. This was done approximately once per minute. During the second session, the dipper was presented 30 times, with approximately 1 min between presentations. The duration of presentation was reduced from 10 sec at the beginning of the session to 4 sec by the end. All subjects were reliably obtaining all reinforcers by the end of the second session.

Following dipper training, each subject was

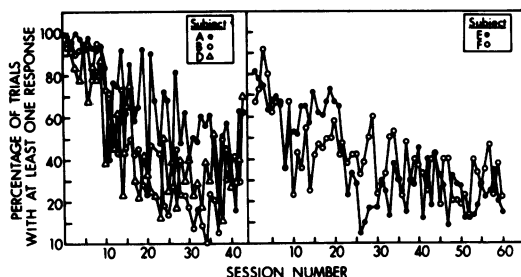


Fig. 1. The percentage of trials containing a response plotted across training sessions.

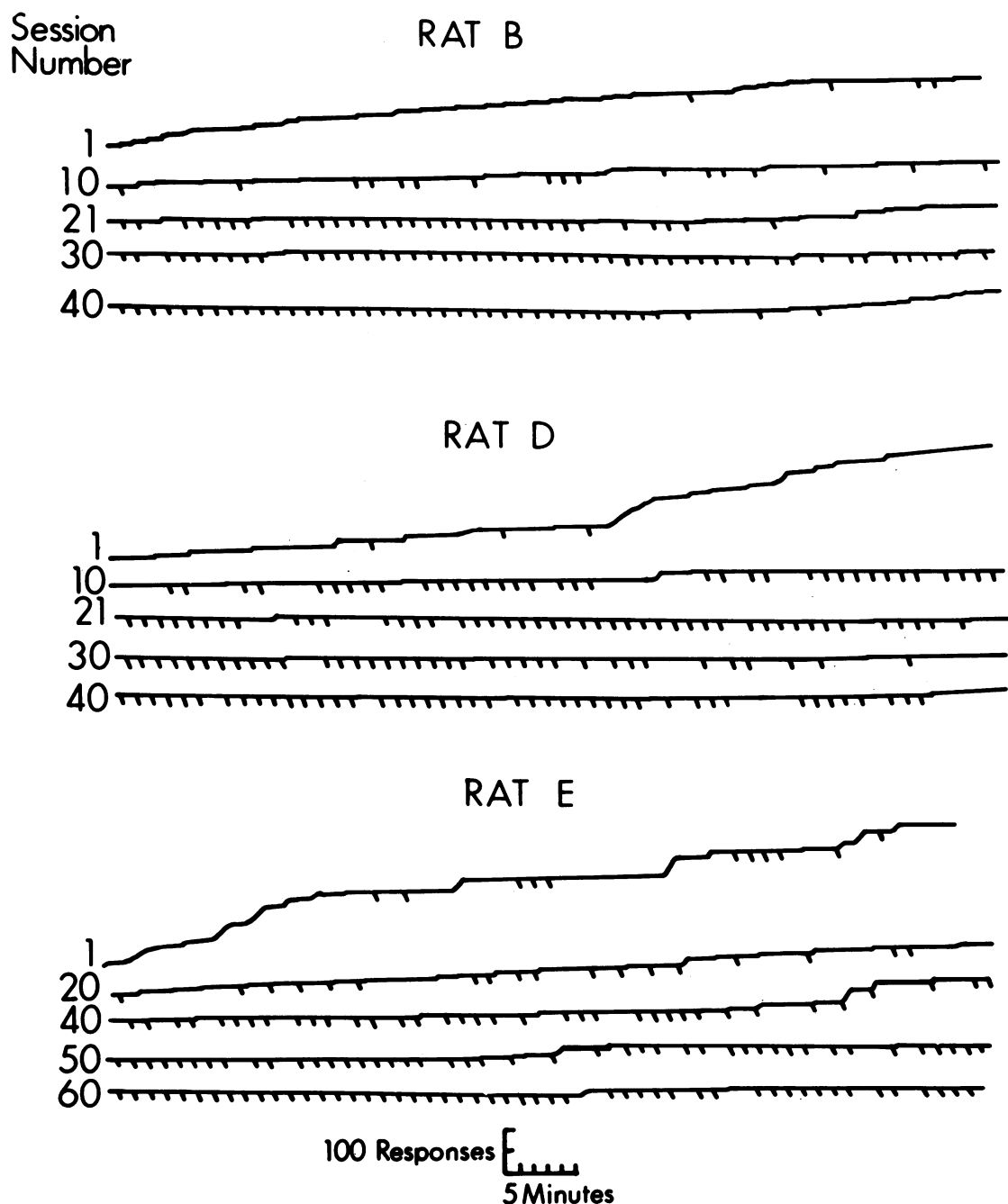


Fig. 2. Representative cumulative records from Subjects B, D, and E. Pen slashes represent reinforcer deliveries.

given a total of 50 daily sessions of the omission procedure used in Experiment I. These 50 sessions were divided into two 25-session blocks, which were differentiated by the consequences of a response made during the trial. Two animals, I and J, had signal light presentation (S) and then blackout (B) as a re-

sponse consequence for the initial 25 sessions, and had blackout followed by signal light presentation for the final 25 sessions. The order of these treatments was reversed for Subjects K and L. Subjects I and K had a bright trial light and dim signal light and J and L had a dim trial light and bright signal light.

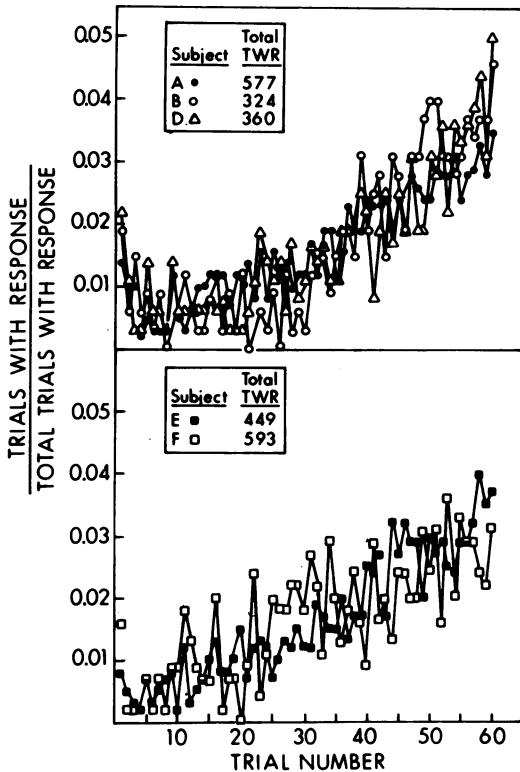


Fig. 3. Temporal distributions of trials containing at least one response. The ratio of the number of trials with a response divided by the total number of trials with a response plotted as a function of trial number. These curves are derived from Sessions 24 to 43 for Subjects A, B, and D and from Sessions 31 to 60 for Subjects E and F.

### RESULTS

The per cent TWR across the 50 sessions is presented in Figure 4. Note that all four animals began to press the lever during the first session and continued to do so for the duration of this portion of the study. While these animals showed a tendency to respond on a somewhat smaller proportion of trials than the animals in Experiment I, they were still consistently omitting roughly a quarter of the programmed reinforcements during each session. Graphs of the temporal distributions (Figure 5), produced using the data-reduction techniques outlined in Experiment I, show greater variability than those presented in Figure 2, but a similar trend is apparent. The increased variability would be expected, since present distributions are based on fewer sessions than those of Experiment I. Again, there is generally a strong linear component to the

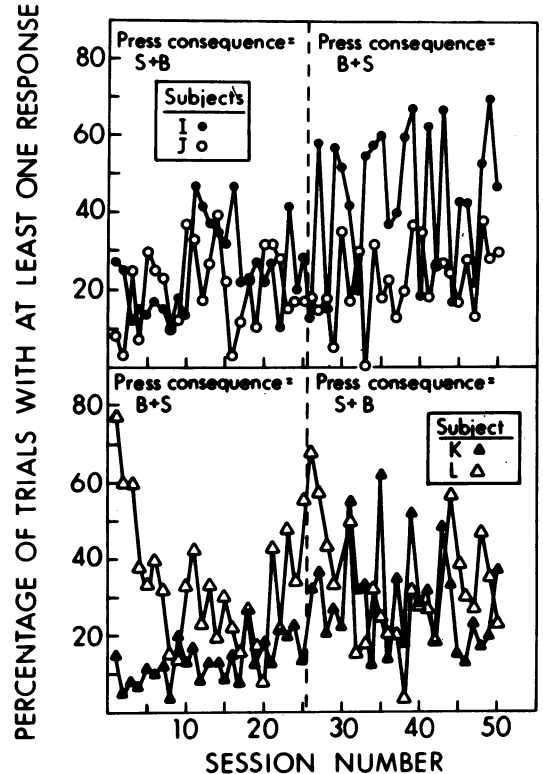


Fig. 4. The percentage of trials containing a response plotted across training sessions. The vertical broken line indicates the point at which the ordering of the stimulus changes contingent on the initial lever press was reversed. S indicates presentation of the signal light and B indicates blackout.

curves and the regression coefficients for linear components are similar to those found for the five animals in the first experiment.

It has been demonstrated up to this point that both naive and nonnaive rats, when exposed to the fixed-trial omission procedure employed in this study, will initiate and maintain responding at moderate levels. Furthermore, after extended exposure to the schedule, the distribution of responding within each session fell into a consistent temporal pattern. The purpose of Experiment III was to determine whether procedural alterations that would normally be expected to reduce responding would have any effect on TWR or the temporal distribution of TWR.

### EXPERIMENT III

#### METHOD

##### Subjects

Animals E and F from Experiment I and Subjects I, J, K, and L from Experiment II

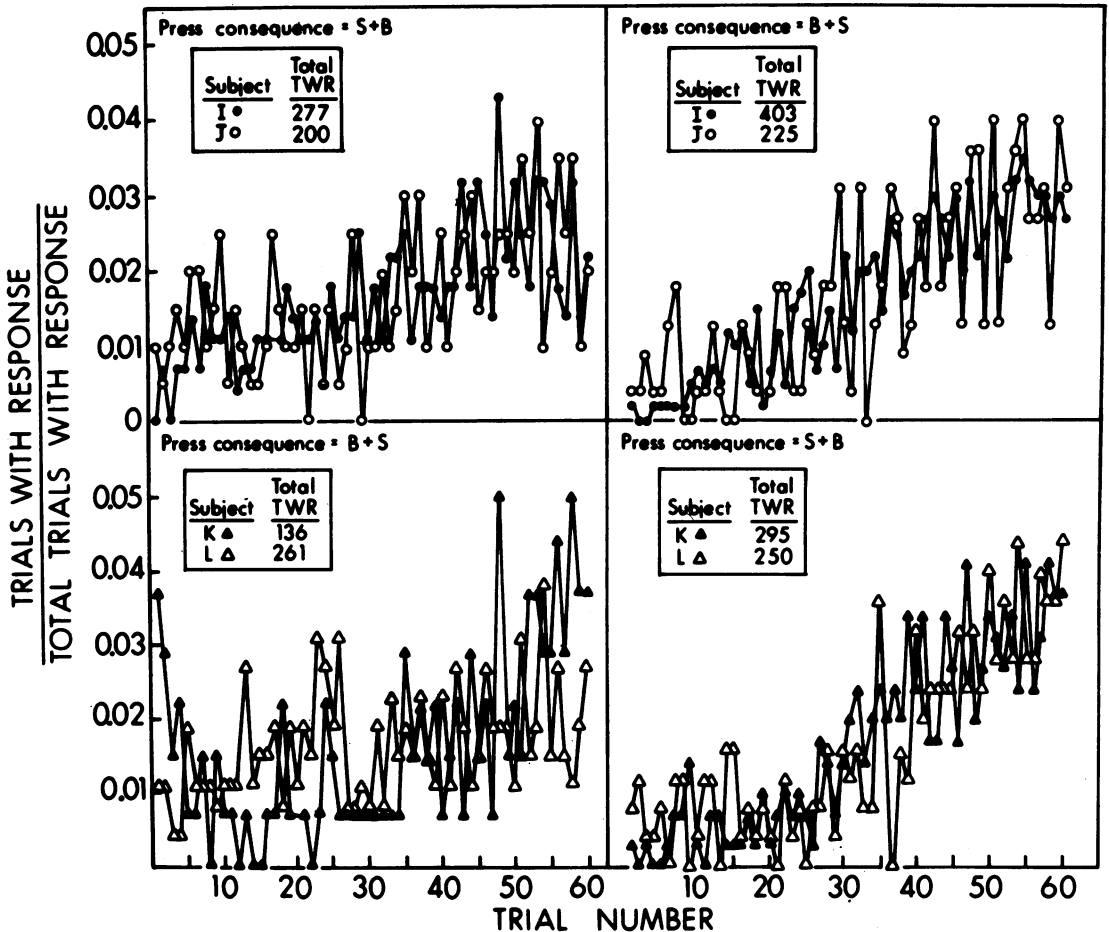


Fig. 5. Temporal distributions of trials containing at least one response, plotted as in Figure 3. The curves on the left side of the figure are derived from Sessions 10 to 25 and the curves on the right side are from Sessions 35 to 50.

served. They were maintained on the same feeding schedule used in the previous experiments.

#### Apparatus

The same as used in Experiments I and II.

#### Procedure

Immediately after completing training in one of the initial experiments, all six subjects were exposed to one of three variants of the original omission procedure. Animals I and J were given 35 sessions of training in which the procedures were identical to those employed in the final 25 sessions of Experiment II, except that primary reinforcement was never provided. The effect of pressing the lever was still blackout followed by S light during the final 0.5 sec of the trial. Following 35 sessions with-

out reinforcement, I and J received 40 additional sessions of training in which both press feedback and reinforcement were eliminated. In this condition, there were no scheduled consequences for lever pressing, although the T and S lights continued to cycle. Animals K and L were given 21 sessions identical in procedure to the final 40 sessions just described for I and J. That is, reinforcement and consequences of pressing the lever were removed. Finally, E and F received 22 sessions identical to Experiment I, except that there were no stimulus-light changes; the lever was continuously transilluminated with the bright light for Subject E and the dim light for Subject F. This constituted a completely unsignalled, fixed-trial omission procedure. Reinforcement continued to be delivered on trials where no response occurred.

Table 1

Conditions and median percentage of trials with response (TWR) for Experiment III.

Subject	Sessions	Rein- forcement	Press Feed- back	Stimulus Light Changes	Median % TWR
I	1-35	No	Yes	Yes	82%
J	1-35	No	Yes	Yes	50%
I	36-75	No	No	Yes	28%
J	36-75	No	No	Yes	12%
K	1-21	No	No	Yes	17%
L	1-21	No	No	Yes	38%
E	1-22	Yes	No	No	12%
F	1-22	Yes	No	No	10%

### RESULTS

Table 1 summarizes the conditions used in Experiment III and the median per cent TWR for each condition.

#### *Elimination of Reinforcement*

The left side of Figure 6 shows the per cent TWR for Subjects I and J after reinforcement was eliminated. Responding increased during this extinction procedure relative to the omission procedure used in Experiment II (see Figure 4). At about Day 25, the per cent TWR tended to stabilize at about 75% and 55% for I and J respectively. The temporal distributions of responding during the final 20 days of this period are presented in Figure 7. The tendency for these curves to flatten during the later trials is a ceiling effect resulting from responses occurring during virtually all of the later trials. It is apparent, especially for Subject J, that the probability of responding increased as the session progressed. The ceiling effect in these distributions, however, makes it difficult to compare them to those produced in Experiment II.

#### *Elimination of Press Feedback*

Since the complete elimination of reinforcement augmented responding in Subjects I and J, the remaining consequences of pressing the lever, the production of blackout, were eliminated. The effects of this change in condition on per cent TWR are presented in the right-hand side of Figure 6. The reduction in responding was rapid and profound, with both subjects responding on relatively few trials by the end of this 40-day segment. Figure 8 shows that even after reinforcement and all stimulus changes associated with pressing the lever were eliminated, the probability of re-

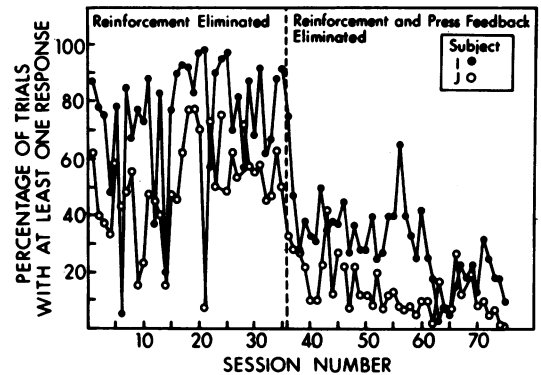


Fig. 6. The percentage of trials containing a response plotted across training sessions. The vertical broken line indicates the point at which all stimulus-light changes contingent on an initial lever press (*i.e.*, press feedback) were eliminated.

sponding increased progressively during the average session.

Figure 9 shows the performance of Subjects K and L after reinforcement and response feedback were eliminated. There is a slight reduction in per cent TWR for K, but little, if any, change for L. Their temporal distributions of responding (Figure 10) showed the persistent pattern already repeatedly seen and appear quite similar to those produced by K and L in Experiment II (see Figure 5).

#### *Elimination of Stimulus Changes*

During this condition for Subjects E and F, the negative contingency between lever pressing and reinforcement remained identical to that in Experiment I; however, all changes in the stimulus lights were eliminated. The results from this training are presented in Fig-

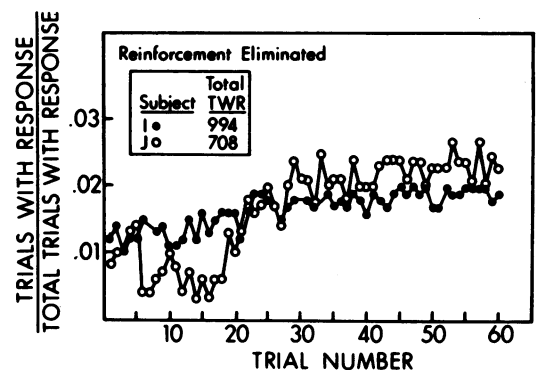


Fig. 7. Temporal distribution of trials containing at least one response, plotted as in Figure 3. These curves are derived from Sessions 16 to 35 of Experiment III.

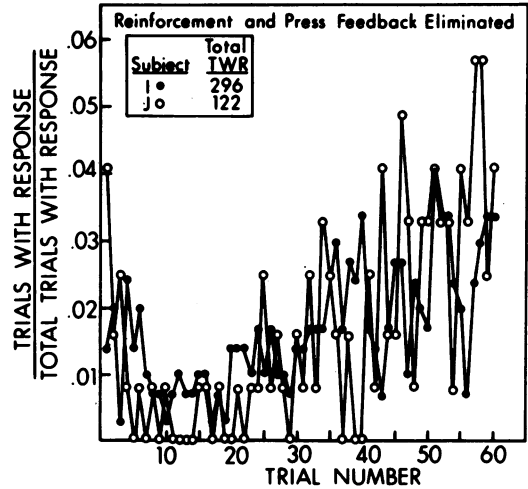


Fig. 8. Temporal distributions of trials containing at least one response, plotted as in Figure 3. These curves are derived from Sessions 56 to 75 of Experiment III.

ures 11 and 12. There was a reduction in per cent TWR relative to the terminal level of responding seen in Experiment I (see Figure 1). Of greater interest is Figure 12, which indicates that responding was unsystematically distributed throughout the session. There was no

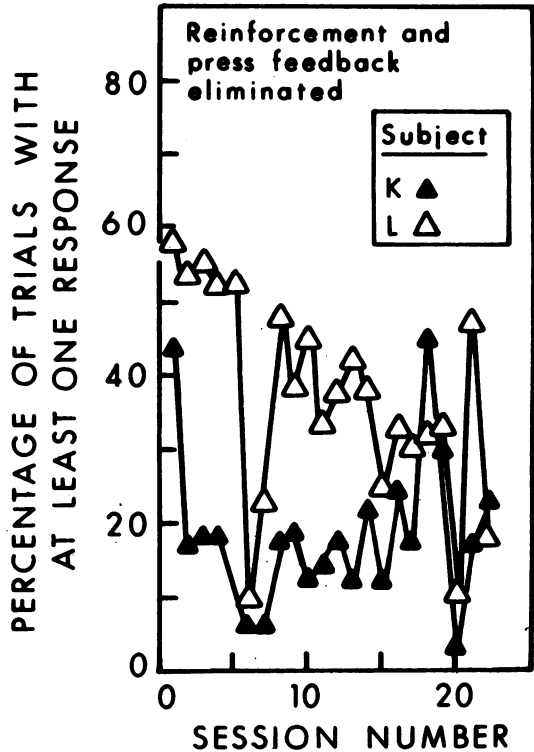


Fig. 9. The percentage of trials containing a response plotted across training sessions.

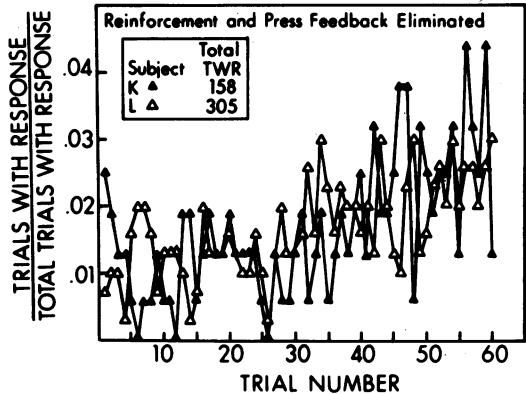


Fig. 10. Temporal distributions of trials containing at least one response, plotted as in Figure 3. These curves are derived from Sessions 7 to 21 of Experiment III.

tendency to respond more frequently toward the end of the session.

DISCUSSION

One of the main findings from this study is that both naive and nonnaive rats will initiate and maintain lever-press behavior when exposed to an omission procedure. A recent study by Atnip (1977) also investigated omission training in rats and his results are quite consonant with those presented here. The per cent TWR in both studies showed considerable

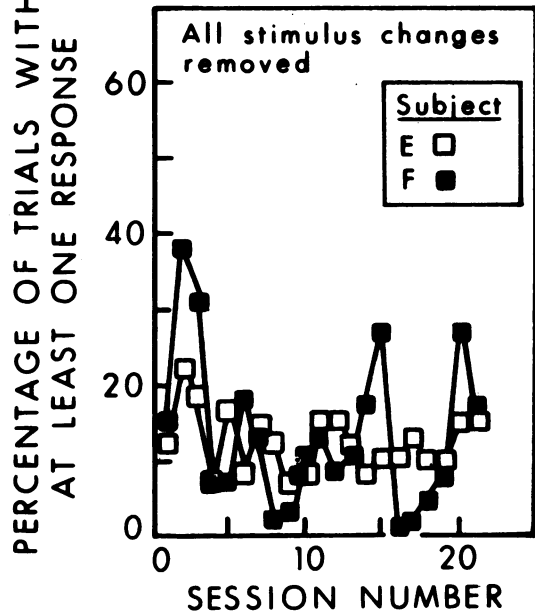


Fig. 11. The percentage of trials containing a response plotted across training sessions.

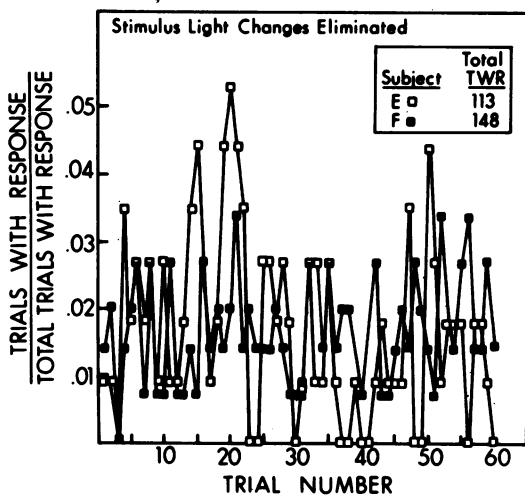


Fig. 12. Temporal distributions of trials containing at least one response, plotted as in Figure 3. These curves are derived from Sessions 8 to 22 of Experiment III.

intrasubject and intragroup variability during omission training but, in general, the median per cent TWR appears quite comparable. It is also of interest to note that no systematic differences were seen in omission-training performance in either study between subjects that had been exposed only to an omission schedule and subjects that had prior reinforcement history that included reinforced lever pressing.

Another result from the present study is that rats exposed to a fixed-trial omission procedure distribute the trials on which they respond within a session in a regular and reliable pattern. It must be emphasized that the relative temporal distributions on which the last statement is based (Figures 4, 6, 8, 9, 11, 13) are obtained by averaging a given subject's data from a number of sessions. As such, these curves may not directly reflect the daily patterns of responding used to generate them. For example, the probability of a TWR may increase steadily during a session, or this probability might show a drastic increase at some point during the session, with the point at which this occurs varying across sessions. Inspection of the cumulative records revealed trends more consistent with the first possibility than the second, but neither can be conclusively eliminated.

Regarding this within-session pattern, a number of explanations might be based on nonspecific aspects of the training situation, rather than the negative contingency between

response and reinforcer. For example, there may be an interaction between the probability of response and the amount of sucrose consumed, but several factors argue against this. It is feasible that 100 to 200 mg of sucrose may be sufficient to produce some degree of satiation in a 175-g rat. It is not clear, however, why this satiation would lead to an increased likelihood of responding, or why this trend toward increased responding late in a session would persist even when no sucrose is available for consumption (Subjects I, J, K, and L, Experiment III).

One appealing explanation of this temporal pattern is based on the interaction between the effects of response-reinforcer and stimulus-reinforcer relationships. The importance of this interaction has been stressed by a number of authors (Atnip, 1977; Hearst and Jenkins, 1974; Schwartz and Gamzu, 1977; Woodruff, Conner, Gamzu, and Williams, 1977), and such a dynamic interplay would imply some temporal pattern based on the constantly fluctuating correlations between stimulus, response, and reinforcer. The most likely pattern implied by such an analysis, alluded to by Schwartz (1972), was not duplicated here. The probability of a TWR increased in a monotonic fashion, except for some cases in which the initial trials of the session showed a briefly decreasing probability. It is conceivable that a longer session might have revealed a waning effect, but more data are required to evaluate this possibility.

Several other aspects of these results are inconsistent with a formulation based on shifting control between stimulus- and response-reinforcer contingencies. A major problem arose when reinforcement was eliminated. Responding persisted and the temporal patterning of responding persisted, yet reinforcement was no longer available to be correlated with stimulus or response. One might speculate that the stimulus-light changes that provide feedback for a lever press have acquired properties as secondary reinforcers but, even when this feedback was eliminated, the temporal pattern persisted, although the absolute level of responding was reduced.

Another puzzling facet of this effect is the relatively long exposure to omission training required to achieve a steady temporal pattern. If stimulus- and response-reinforcer contingencies operate over a short time span, as

would be expected from the fact that the pattern repeats itself daily, why should their effects not be apparent immediately, rather than after 20 to 25 hr exposure to the schedule? As the cumulative records in Figure 2 indicate, a good deal of responding occurred during the initial weeks of exposure to the procedure before any orderly temporal pattern developed.

Herrnstein and Loveland (1972) suggested that stimulus change contingent on responding might possess reinforcing properties, and thus be of some use in explaining the unexpected results related to autoshaping and omission procedures. This suggestion is consistent with the present data, since the condition producing the least responding and an apparently random temporal distribution (Subjects E and F, Experiment III) was also the condition in which all stimulus change was eliminated. Note, however, that for Subjects I, J, K, and L in Experiment III, what stimulus changes did occur were independent of responding, and yet responding was maintained. It does not appear that stimulus change need be response contingent in order to have effects on responding. This raises the possibility that stimulus change, since it may provide a sufficient condition for the maintenance of low levels of responding, could account for many of the results in the omission-training literature.

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